CLAIMS

The invention claimed is:

1. A method for forming a variable astigmatic focal beam spot to cut a substrate, said method comprising the steps of:

generating a raw laser beam;

expanding said raw laser beam;

modifying said expanded beam such that said modified beam is collimated in one principal meridian and converging in another principal meridian;

focusing said modified beam having two separate focal points to produce an astigmatic focal beam spot having an elongated shape; and

directing said astigmatic focal beam spot at said substrate to obtain at least a partial cut in said substrate.

2. The method of claim 1 wherein said raw beam is generated using a solid state laser.

3. The method of claim 2 wherein said raw beam is generated in a UV range less than about 400 nm.

4. The method of claim 3 wherein said raw beam is generated with a pulse duration less than about 40 ns.

5. The method of claim 1 wherein the step of expanding said raw beam includes passing said raw beam through a beam expanding telescope.

6. The method of claim 1 wherein the step of modifying said expanded beam includes passing said expanded beam through an anamorphic lens system comprising a cylindrical plano-concave lens and a cylindrical plano-convex lens.

7. The method of claim 1 further comprising the step of varying the convergence of said modified beam.

8. The method of claim 1 wherein the step of modifying said expanded beam includes passing said expanded beam through a single anamorphic lens to provide a fixed convergence.

9. The method of claim 1 further comprising the step of symmetrically cropping low intensity edges of said expanded beam.

10. The method of claim 1 wherein the step of focusing said modified beam comprises passing said modified beam through a beam focusing lens, wherein said focused beam has two separate focal points, wherein one of said focal points is shorter than a nominal focal length of said beam focusing lens and the other of said focal points is formed generally at said nominal focal length of said beam focusing lens.

11. The method of claim 1 wherein said substrate includes sapphire.

12. The method of claim 11 wherein said substrate includes a GaN layer on said sapphire, and wherein said astigmatic focal beam spot is directed at a surface of said GaN layer such that laser energy is coupled into said GaN layer to cause ablation of said sapphire.

13. The method of claim 1 wherein said substrate is part of a semiconductor wafer including a device layer on said substrate.

14. The method of claim 1 wherein said substrate is made of a material selected from the group consisting of metal, GaAs, silicon, GaP, InP, Ge, alumina, glass and polymers.

15. The method of claim 1 wherein said substrate includes a metal film made of a metal selected from the group consisting of molybdenum and copper.

16. The method of claim 1 wherein said astigmatic focal beam spot has a width of less than about 20 μm.

17. The method of claim 16 wherein said astigmatic focal beam spot has a width of about 5 μm.

18. The method of claim 1 further comprising the step of moving said substrate in a cutting direction along a length of said astigmatic focal beam spot.

19. The method of claim 1 wherein the step of modifying said expanded beam includes creating a plurality of separated astigmatic beamlets.

20. The method of claim 19 wherein the step of modifying said expanded beam includes controlling at least one of a length of said beamlets and a distance between said beamlets.

21. The method of claim 1 further comprising the step of applying a water soluble protective coating to said substrate before directing said astigmatic focal beam spot at said substrate, said protective coating including at least one surfactant in a water-soluble liquid glycerin.

22. A method for scribing a semiconductor wafer using a laser, said method comprising the steps of:

generating a laser beam;

forming at least one astigmatic focal beam spot by modifying said laser beam such that said modified beam has two separate focal points and said astigmatic focal beam spot has an elongated shape; and

directing said astigmatic focal beam spot at a surface of said semiconductor wafer, wherein said astigmatic focal beam spot is applied with a set of parameters until at least a partial cut in said semiconductor wafer is obtained.

23. The method of claim 22 further comprising:

moving said semiconductor wafer in a cutting direction along a length of said astigmatic

focal beam spot to make at least one cut in an x direction on said semiconductor wafer;

rotating said semiconductor wafer about 90 degrees; and

moving said semiconductor wafer in a cutting direction along a length of said astigmatic focal beam spot to make at least one cut in a y direction on said semiconductor wafer.

24. The method of claim 22 wherein the step of forming said astigmatic beam spot uses an anamorphic lens system to receive an expanded, collimated beam and to produce a modified beam that is collimated in one principal meridian and converging in another principal meridian.

25. The method of claim 22 wherein the step of forming said astigmatic beam spot uses a beam focusing lens to focus said beam spot such that one of said focal points is shorter than a nominal focal length of said beam focusing lens and the other of said focal points is formed generally at said nominal focal length of said beam focusing lens.

26. The method of claim 22 further comprising the step of varying said astigmatic focal beam spot.

27. The method of claim 24 wherein said anamorphic lens system comprises a cylindrical plano-concave lens and a cylindrical plano-convex lens.

28. The method of claim 27 further comprising the step of varying said astigmatic focal beam spot by varying a spacing between said cylindrical plano-concave lens and said cylindrical plano-convex lens.

29. The method of claim 22 wherein the step of forming said astigmatic focal beam spot comprises the steps of:

generating a raw laser beam;

expanding said raw laser beam;

modifying said expanded beam such that said modified beam is collimated in one principal meridian and converging in another principal meridian; and

focusing said modified beam to produce said astigmatic focal beam spot.

30. The method of claim 22 wherein the step of forming said at least one astigmatic focal beam spot includes forming small segments of separated astigmatic beamlets.

31. The method of claim 22 further comprising the step of translating said semiconductor wafer in a cutting direction along a length of said astigmatic focal beam spot to make a plurality of cuts in said semiconductor wafer.

32. The method of claim 22 wherein said semiconductor wafer includes a sapphire substrate.

33. The method of claim 32 wherein said semiconductor wafer includes a GaN layer on said sapphire substrate, and wherein said astigmatic focal beam spot is directed at said GaN layer such that laser energy is coupled into said GaN layer to cause ablation of said sapphire.

34. A method for separating semiconductor wafers into dies, said method comprising the steps of:

generating a laser beam;

forming at least one astigmatic focal beam spot by modifying said laser beam such that said modified beam has two separate focal points and said astigmatic focal beam spot has an elongated shape;

directing said astigmatic focal beam spot at a surface of a semiconductor wafer, wherein said astigmatic focal beam spot is applied with a set of parameters until at least a partial cut in said semiconductor wafer is obtained; and

separating said semiconductor wafer into dies using said at least a partial cut.

35. A beam delivery system comprising:

a beam expanding telescope for receiving a raw laser beam from a laser and for producing an expanded beam;

at least one variable anamorphic lens system comprising a cylindrical plano-concave lens

and a cylindrical plano-convex lens for receiving said expanded beam and for producing a modified beam collimated in one principal meridian and converging in another principal meridian; and

a beam focusing lens for receiving said modified beam and focusing said modified beam such that said focused beam has two separate focal points, wherein one of said focal points is shorter than a nominal focal length of said beam focusing lens and the other of said focal points is formed generally at said nominal focal length of said beam focusing lens.

36. The beam delivery system of claim 35 further comprising a beam shaping iris between said beam expanding telescope and said variable anamorphic lens system for cropping out low intensity edges of said expanded beam.

37. The beam delivery system of claim 35 further comprising at least one bi-prism between said beam expanding telescope and said variable anamorphic lens system for dividing said expanded beam.

38. The beam delivery system of claim 35 further comprising a set of bi-prisms between said beam expanding telescope and said variable anamorphic lens system for dividing said expanded beam and controlling separation of said divided beams.

39. The beam delivery system of claim 35 further comprising an array of variable anamorphic lens systems for creating a plurality of separated astigmatic beamlets.

40. A method for scribing a sapphire substrate having a layer of GaN, said method comprising the steps of:

directing pulses of laser energy forming an astigmatic focal beam spot at a surface of said GaN on said sapphire substrate using a solid state laser, wherein said pulses couple laser energy into said GaN layer to induce ablation of said sapphire substrate; and

causing said pulses to impact said sapphire substrate in a scribe pattern to cut scribe lines in said sapphire substrate.